CONODONTS FROM NEAR THE MIDDLE/UPPER DEVONIAN BOUNDARY IN NORTH CORNWALL

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ABSTRACT. Conodonts of the *Polygnathus varcus* (Middle Devonian, Givetian) Zone and the lower (Upper Devonian) and upper part of the Lower *Pol. asymmetricus* Zone (Upper Devonian, Frasnian Iα) are reported from thin turbidite limestones in the upper Trevose Slates, Marble Cliff Beds, and lower Longcarrow Cove Tuffs and Slates, respectively, near Padstow, North Cornwall. The localities include the south side of Trevone Bay and the overturned section along the coast at Marble Cliff. The fauna of the *Schmidtognathus hermanni–Pol. cristatus* Zone, which in Germany marks the Middle/Upper Devonian boundary of the conodont chronology, was not recovered, although some species that enter in that zone (*Pol. cristatus* [?] Hinde, *S. wittekindti* Ziegler and *S. peracutus* (Bryant)) are found in the Marble Cliff Beds, associated with *Palmatolepis transitans* Müller, *Pol. asymmetricus ovalis* Ziegler and Klapper, *Pol. asymmetricus asymmetricus* Bischoff and Ziegler, and abundant *Pol. decorosus* Stauffer *s.l.* The first undoubted Upper Devonian conodonts occur in the Longcarrow Cove Tuffs and Slates near the base of Marble Cliff, where faunas include *Ancyrodella rotundiloba* (Bryant).

REINVESTIGATIONS of ammonoid cephalopods (House 1956, 1961, 1963) from the highly deformed grey slates around Padstow, North Cornwall, have revealed Middle Devonian faunas in rocks long thought to be entirely Upper Devonian in age. Several ammonoid horizons are known in the district and the sequence of faunas enabled House to unravel the stratigraphic succession and establish a correlation with the standard sequence in the Rheinisches Schiefergebirge. Although the broad aspects of the stratigraphy and structure (Gauss 1966, 1967) have been worked out, many parts of the puzzle remain unsolved because of the lack of faunal evidence in critical parts of the succession. This contribution attempts to refine the biostratigraphy of the coastal section near the Middle/Upper Devonian boundary by means of conodonts.

The Middle Devonian Trevose Slates are situated on the southern limb of the St. Minver Synclinorium (House 1961) whose axis lies north of Padstow, within Upper Devonian purple and green slates (upper Frasnian to Fammenian) (text-fig. 1). The grey slates reappearing on the northern limb are overlain by a thick series of pillow lavas (Pentire Point Pillow Lavas) before the entry of purple and green slates. The coastal succession on the southern limb appears to be more complete, and here the Trevose Slates begin in the upper Eifelian (Booby's Bay) and extend into the upper Givetian (Trevone Bay). The fauna of the uppermost Givetian *Maenioceras terebratum* Zone is well represented in the Pentonwarra Point Goniatite Band on the south side of Trevone Bay (House 1963). The fauna of the succeeding lower Frasnian (lowermost Upper Devonian) *Pharciceras lunulicosta* (Iα) Zone has not been found anywhere in the district, but the middle Frasnian *Manticoceras cordatum* (I (β) γ) Zone-fauna is known from several localities, including the dark grey slates at Merope Island (Merope Island Beds), 0·6 miles (1 km.) north of Trevone Bay (House 1961, 1963). Between the Trevose Slates and the Merope Island Beds and situated on the overturned limb of a major recumbent syncline (Gauss 1966) are 220 ft. (67 m.) of alternating limestone and shale exposed at Marble Cliff (Marble Cliff Beds and lower Longcarrow Cove Tuffs and Slates) which are succeeded to the north by grey slates with tuff beds, agglomerate, and minor limestones

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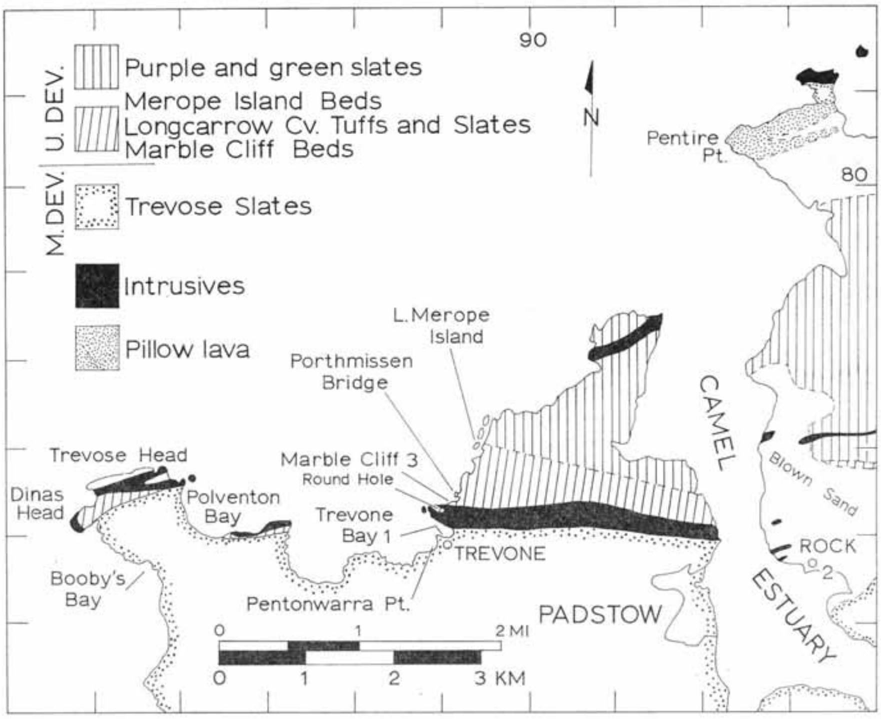
(House 1961, House and Selwood 1966). The Marble Cliff succession dips south beneath the dolerite sill that forms the prominent headland north of Trevone Bay.

No ammonoids are known from either the Marble Cliff Beds or Longcarrow Cove Tuffs and Slates, but House (1963) tentatively placed the Middle/Upper Devonian boundary between them, assigning the Marble Cliff Beds to the Givetian largely on the



TEXT-FIG. 1. Geological sketch-map of Padstow area showing conodont localities.

evidence of *Wedekindella* (a characteristic Middle Devonian genus) associated with similar limestones to the west at Poventon Bay. House and Selwood (1966, p. 53) recorded an upper Givetian conodont age for the Marble Cliff Beds based on an unpublished preliminary study by F. H. T. Rhodes of a sample collected from loose blocks at the base of the cliff (House 1967, personal communication); this assignment was based on a correlation with the conodont zonation of Bischoff and Ziegler (1957) from the Rheinisches Schiefergebirge. Since the report of Bischoff and Ziegler a more refined conodont zonation has been established within the framework of the standard ammonoid zonation (Ziegler 1958, 1962*a*, 1966*b*). This conodont chronology has proved to be extremely useful for precise inter-continental correlation (see Glenister and Klapper 1966) and it is particularly refined around the Middle/Upper Devonian boundary.

The samples were collected from the coastal sequence around Padstow during the spring tides of October 1967 and January 1968.

CONODONT ZONATION ACROSS THE MIDDLE/UPPER DEVONIAN BOUNDARY

Ziegler (1966*b*), Krebs and Ziegler (1966), Glenister and Klapper (1966), and Orr and Klapper (1968), among others, have thoroughly reviewed the relationship between the conodont zonation and the position of the Middle/Upper Devonian boundary and only a few pertinent details are noted here. In terms of the standard ammonoid zonation in the Rheinisches Schiefergebirge, the top of the Middle Devonian is defined as the top of the *Maenioceras terebratum* Zone and the base of the Upper Devonian as the base of the *Pharciceras lunulicosta* Zone (Iα), with the entry of *Pharciceras*; this boundary has been traditionally equated with the Givetian/Frasnian stage boundary in Belgium, but the correlation has still to be proven. An exact boundary horizon cannot be placed in Germany because there is a gap between the ranges of *Maenioceras* and *Pharciceras*. It is within this critical interval that Ziegler (1966*b*) defined the Middle/Upper Devonian boundary in terms of conodonts.

The *Polygnathus varcus* Zone (*varcus*-Subzone of Bischoff and Ziegler 1957) corresponds to the highest part of the *M. terebratum* Zone and is therefore regarded as uppermost Middle Devonian (Ziegler 1962*b*, p. 16). The *Pol. varcus* Zone begins with the entry of *Pol. varcus* and is characterized by abundant *Pol. varcus* and *Pol. linguiformis* without *Spathognathodus bipennatus*. Wittekindt (1966, pp. 627, 628) subdivided the *Pol. varcus* Zone into a *varcus*-Zone without *Pol. linguiformis transversus* and a succeeding *transversus*-Zone with *Pol. linguiformis transversus*. Because the well-known species *Pol. varcus* and *Pol. linguiformis* dominate the fauna of the *Pol. varcus* Zone as originally defined, and because *Pol. linguiformis transversus* is rare, Krebs and Ziegler (1966, p. 747) preferred an informal subdivision of the *Pol. varcus* Zone into a lower and upper part; this interpretation is followed here.

The *Schmidtognathus hermanni–Polygnathus cristatus* Zone (Ziegler 1966*b*) follows the *Pol. varcus* Zone and comprises the range of *S. hermanni* before the entry of *Pol. asymmetricus* and *Palmatolepis transitans*. The lower boundary of the zone is not precisely defined, as a few early growth stages of *S. hermanni*, as well as forms transitional between *Pol. decorosus s.l.* and *S. hermanni*, occur in horizons that Ziegler regards as still in the *Pol. varcus* Zone (Ziegler (1966*b*, tables 1, 2, p. 659). Above the base of the *S. hermanni–Pol. cristatus* Zone, *S. hermanni* is joined by *Pol. cristatus* and three new species of *Polygnathus* and three of *Schmidtognathus*, but not at a single horizon as implied by Ziegler (1966*b*, text-fig. 2). The details of Ziegler's range-charts show the entry of these species in a staggered sequence, with some of the species (*S. hermanni*, *S. pietzerni*) appearing before *Pol. cristatus*, as in the least condensed Koppen section at Rhenegge near Adorf. Several of these species, in addition to *S. hermanni* and *Pol. varcus*, linger on into the succeeding Lower *Pol. asymmetricus* Zone, whose lower boundary is defined by the entry of *Pol. asymmetricus* and *Pal. transitans*.

The position of the *S. hermanni–Pol. cristatus* Zone relative to the Middle/Upper Devonian boundary is still a problem as the zonal fauna has not been found in rocks bearing ammonoids. In the Rheinisches Schiefergebirge the zone appears to fill the gap in the ammonoid chronology (Ziegler 1966*b*) and is thus a problematical interval between the Middle and Upper Devonian. It is clear from Ziegler's analysis (pp. 672, 673) that the *S. hermanni–Pol. cristatus* Zone represents an important interval in conodont evolution during which simple ancestral conodonts (*Pol. decorosus s.l.*) gave rise to diverse and morphologically 'advanced' platform conodonts such as *Schmidtognathus* and the *Pol. cristatus* group. *Pol. cristatus* in turn lead to *Pol. asymmetricus*, the stem form of the line leading to *Palmatolepis*, a particularly significant genus in Upper Devonian faunas. Thus in terms of conodont evolution Ziegler (1966*b*, pp. 660, 661) regarded the lower part of the *S. hermanni–Pol. cristatus* Zone (without *Pol. cristatus*) as Middle Devonian and the more diverse upper part as Upper Devonian.

The succeeding Lower *Pol. asymmetricus* Zone is informally subdivided into a lower part and upper part based on the first appearance of *Ancyrodella rotundiloba* (Ziegler 1962*b*, p. 17, 1966*b*, p. 662). Krebs and Ziegler (1966, pp. 748, 749) assembled evidence that proves beyond doubt that the upper part of the Lower *Pol. asymmetricus* Zone (with *A. rotundiloba*) lies within the *Pharciceras lunulicosta* Zone (Iα) and is thus firmly Upper Devonian; this correlation has since been confirmed in Australia (Glenister and Klapper 1966, p. 785) and North America (Orr and Klapper 1968, p. 1069).

Krebs and Ziegler also suggested that the lower part of the Lower *Pol. asymmetricus* Zone probably falls in the *P. lunulicosta* Zone (Iα) but offered no concrete evidence. However, recent ammonoid collections from the classic section at Martenberg near Adorf seem to support this interpretation. In April 1968, Dr. J. Kullmann, in a field party with Professors W. Ziegler, M. R. House, and the author, discovered a new horizon of pharciceratids low down in the Roteisenstein, which narrows the gap in the ammonoid sequence, as typical Middle Devonian ammonoids are found only 0·30 m. below. The new horizon lies within the 1·0 m. interval between Ziegler's (1958) samples 0 (*Pol. varcus* Zone) and 1 (upper part of Lower *Pol. asymmetricus* Zone). It remains to be seen whether the faunas of the lower part of the *Pol. asymmetricus* Zone or the *S. hermanni–Pol. cristatus* Zone can be recovered from the critical interval; Professor Ziegler has made collections and is reviewing the details of the sequence.

The base of the Middle *Pol. asymmetricus* Zone is defined by the first occurrence of *Palmatolepis punctata*, associated with *Pol. asymmetricus*, *A. rotundiloba*, and *A. gigas*, among others; at Martenberg this zone corresponds to the *Pharciceras–Schichten* (Iα) as originally defined by Wedekind (1913). The Middle *Pol. asymmetricus* Zone has been recognized in Australia (Glenister and Klapper 1966, p. 785) and Alberta, Canada (Pollock 1968, p. 442), but its position in other North American sections is difficult to determine because *Palmatolepis punctata* is either not found or is found associated with higher conodont zones equivalent to the *Manticoceras cordatum* (I (β) γ) Zone. Müller and Clark (1967) assigned the Squaw Bay Limestone of Michigan, with *A. rotundiloba* and *Pol. asymmetricus ovalis*, to the Middle *Pol. asymmetricus* Zone but Orr and Klapper (1968, pp. 1068, 1069) disagreed and assigned the Squaw Bay and the supposedly equivalent tongue of the Genundewa Limestone exposed at Eighteenmile Creek, New York, to the upper part of the Lower *Pol. asymmetricus* Zone. In Orr and Klapper's view both horizons have identical faunas, which include *Pol. dengleri* in addition to *A. rotundiloba*. They regard *Pol. dengleri* as the diagnostic species because it has not been reported higher than the upper part of the Lower *Pol. asymmetricus* Zone in the German sequence (Ziegler 1958, tables 2, 10; 1962*b*, p. 17); following this criterion Clark and

Ethington's (1967) fauna from Mary's Mountain, Nevada, should also be reassigned to the upper part of the Lower *Pol. asymmetricus* Zone. Krebs and Ziegler (1966, p. 737) assigned a fauna with *A. rotundiloba* and *A. rugosa* from the Walheim section near Aachen, Germany, to the Middle *Pol. asymmetricus* Zone based on the presence of well-developed pointed anterior lobs in specimens figured as *A. rotundiloba* n. subsp. Krebs and Ziegler (1966). In the present report *A. rotundiloba* n. subsp. is interpreted as an early growth stage variant of *A. rotundiloba* (Bryant) *sensu* Müller and Clark (1967). Krebs and Ziegler's fauna could therefore also correspond to the upper part of the lower *Pol. asymmetricus* Zone, which was the alternative correlation considered by these authors.

CONODONT LOCALITIES

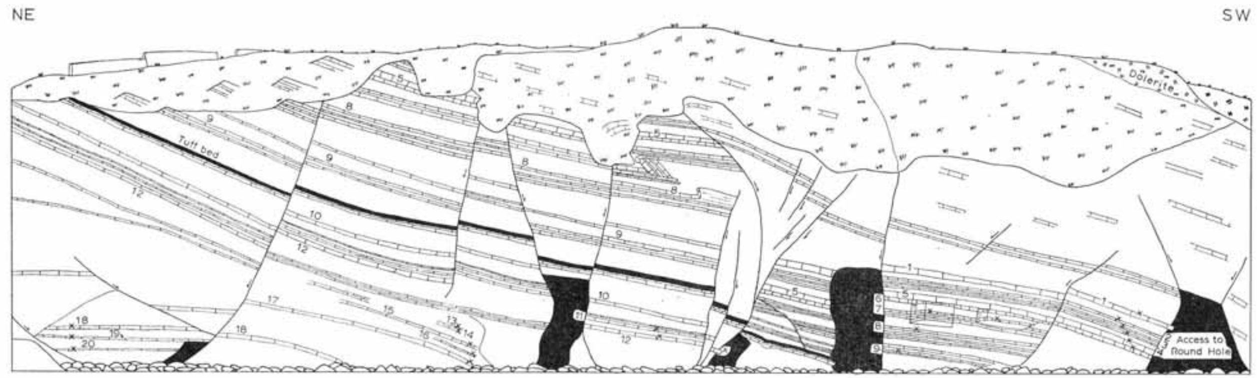
Trevose slates. Thin beds of blue-grey limestone are not uncommon within the grey slates around Padstow, but few horizons can be accurately placed in the generally northward-younging succession. Limestones at several localities, including Trevose Head, Cataclews Point, Padstow, Rock, and further south-east, have long been regarded as equivalent to the well-exposed sequence of closely spaced limestones at Marble Cliff (Reid *et al.* 1910, Dewey 1914). At the type locality, the Marble Cliff Beds are separated from the underlying Trevose Slates by the prominent dolerite sill that extends from Padstow westward to the Trevose Peninsula: on the Trevose Peninsula the Marble Cliff Beds are intruded by the sill. Throughout the area west of the Camel Estuary the critical part of the transition between the Marble Cliff Beds and the Trevose Slates has been obscured by the intrusion, especially where the limestones and shales are adinolized as at Dinas Head and on the peninsula north of Trevone Bay (Fox 1895). The conodont evidence presented here indicates that those limestones lying south of but not directly associated with the sill are older than the Marble Cliff Beds and should be assigned to the Trevose Slates; among these are the limestones around Rock and presumably the limestones with *Agoniatites* and *Wedekindella* from the west and south-west side of Polventon Bay (House and Selwood 1966, p. 53).

Loc. 1. Trevone Bay (SW 890760): Samples 30 and 31. Lower and upper beds of a 2-ft. (0·61 m.) thick series of three limestones alternating with grey slate, dipping south-east in the low cliffs on the south side of the bay. The upper bed (Sample 31) is overlain by 4 ft. (1·22 m.) of slate capped by a prominent 1-foot (0·31 m.) thick bed of brown silty slate. The sequence lies near the top of the Trevose Slates, probably a few feet above the Pentonwarra Point Goniatite Band (Gauss 1968, personal communication).

Loc. 2. Rock (SW 935755): Sample 33. 1-ft. (0·31 m.) thick limestone exposed in the foreshore about 60 yd. (55 m.) east of the sea-wall.

Marble Cliff Beds and Longcarrow Cove Tuffs and Slates. The section at Marble Cliff (Loc. 3: SW 891765) consists of approximately 220 ft. (67 m.) of alternating limestone and shale which are overturned and dip south beneath the dolerite sill (text-fig. 2). There are over 150 individual limestone beds ranging in thickness from less than 1 in. (2·5 cm.) to slightly over 2 ft. (0·61 m.). The thickness of the individual limestones and of the intervening steel-grey shales tends to be constant across the outcrop and the beds are thinner and more widely spaced toward the base of the cliff.

The limestones are light to dark blue-grey bioclastic limestones (packed biomicrite) and are largely composed of fine crinoidal debris. Moulds of *Styliolina* are common in



TEXT-FIG. 2. Sketch of Marble Cliff showing sample-horizons and collecting sites (x); the section is not drawn to scale. The outcrop is about 280 yd. (256 m.) long and the cliff is about 150 ft. (46 m.) high.

the residues and at some horizons (notably Sample 17) these are associated with minute pyritic gastropods, bivalves, ostracods, and rare ammonoid fragments. Sole-markings and graded bedding were noted at a few horizons and these features, and the conodont sequence as well, indicate that the succession is overturned. The only distinctive horizon interrupting this monotonous sequence is a light greenish-grey tuff bed in about the middle of the section. Samples 1–14 are from the Marble Cliff Beds and samples 15–20 are from the Longcarrow Cove Tuffs and Slates (text-fig. 3).

Approximately the lower 75 ft. (23 m.) of the Marble Cliff Beds, between Sample 1 and the sill, is inaccessible in the cliff face. Although the lowermost 26 ft. (8 m.) is accessible in the west wall of Round Hole the limestones are too altered to yield significant conodont faunas; only a single fragment was recovered from a sample near the bottom of the Hole, 24 ft. (7·3 m.) above the intrusive contact. Two distinctive groups of limestone, both consisting of three uniformly spaced beds, provide useful reference horizons in the cliff section. The lower set consists of sample-horizons 2, 3, and 4 and the higher set includes sample-horizon 8 at its base. The top of the Marble Cliff Beds is defined as the base of sample-horizon 15, an irregularly bedded 1-ft. (0·31 m.) thick limestone accessible in the north-east part of the outcrop.

The succeeding more argillaceous sequence near the base of the cliff (samples 15–20) is here included in the Longcarrow Cove Tuffs and Slates. This series of thin, widely spaced limestones reappears across a fault in the section at Porthmissen Bridge (opposite Marble Cliff) and continues northward to Longcarrow Cove, where agglomerates and tuffs enter the succession.

The limestones in the Padstow area appear to be turbiditic in origin and may represent bioclastic debris intermittently swept into a deep water pelagic environment (Goldring *et al.* 1968, p. 7), perhaps from centres of reef accumulation in the more tectonically active part of the basin in South Devon. Dineley (1961) proposed this mechanism to explain similar thin-bedded limestones and shales which accumulated in rapidly subsiding troughs immediately surrounding the South Devon reefs. The greater part of these massive reefs or reef-like (Braithwaite 1966) limestones is lower to upper Middle Devonian, although they continue into the lower part of the Upper Devonian (House and Selwood 1966).

ANALYSIS OF THE CONODONT FAUNAS

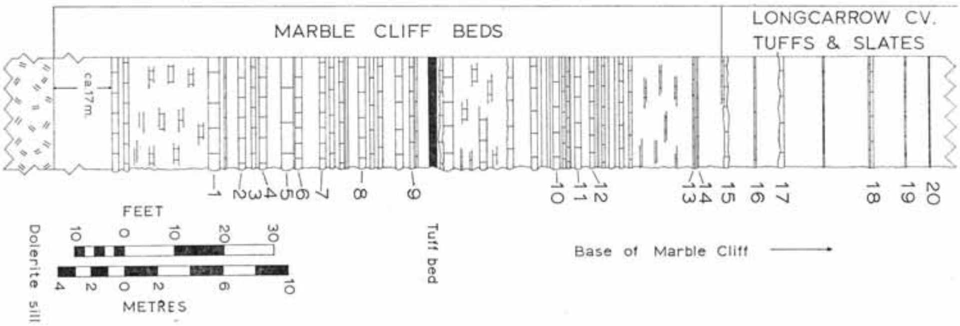
The Trevose Slate horizons at Trevone Bay (Samples 30, 31) produced a fauna dominated by *Pol. linguiformis* and *Pol. varcus* (text-fig. 4) which is indicative of the uppermost Middle Devonian *Pol. varcus* Zone. A similar fauna recovered from Sample 33 at Rock suggests that the scattered limestones thereabout correlate westward with the Trevose Slates at Trevone Bay rather than with the succession at Marble Cliff. The single specimen of *S. hermanni* from Sample 31 is an early growth stage of an intermediate form between *Pol. decorosus s.l.* and *S. hermanni* and is similar to forms figured by Ziegler (1966*b*) from the uppermost part of the *Pol. varcus* Zone in the Rheinisches Schiefergebirge. The specimens of *Pol. linguiformis* and *Pol. varcus* from the Trevose Slates are remarkably similar to the specimens figured by Rhodes and Dineley (1957) from apparently upper Middle Devonian limestones at Bishopsteignton, South Devon. The remaining less stratigraphically important elements of their fauna are rather different and there are no other species in common with the Trevose Slate fauna. Matthews (1962) recorded upper Eifelian conodonts from a structurally complicated sequence at Neal Point, Cornwall, on the River Tamar and his report of *Pol. xylus* (= *Pol. varcus*) and *Pol. varcus* suggests that the *Pol. varcus* Zone is also represented.

The fauna of the Marble Cliff Beds (Samples 1–14) corresponds to the lower part of the *Pol. asymmetricus* Zone and thus indicates a probable lower Upper Devonian age for the limestone sequence. Important forms in the diverse but unevenly distributed fauna include *Pol. asymmetricus asymmetricus*, *Pol. asymmetricus ovalis*, *Pol. dengleri*, and *Palmatolepis transitans*. Although the fauna of the *S. hermanni–Pol. cristatus* Zone is not represented there are several holdovers from this and the preceding *Pol. varcus* Zone, including *Pol. varcus*, *Pol. linguiformis*, *Pol. cristatus*, *Pol.* sp. Ziegler (1966*b*, p. 669), *S. wittekindti*, *S. hermanni*?, and *S. peracutus*.

The upper part of the Lower *Pol. asymmetricus* Zone, which corresponds to the lower Upper Devonian *Pharciceras lunulicosta* Zone (Iα), begins at the base of the Longcarrow Cove Tuffs and Slates (Samples 15–20) with the entry of *Ancyrodella rotundiloba*. The fauna is less diverse than that of the Marble Cliff Beds and some stratigraphically important forms which range above the lower part of the Lower *Pol. asymmetricus* Zone were not recovered, such as *Pol. asymmetricus*, *Pol. cristatus*, and *Pal. transitans*. In addition to *A. rotundiloba*, the fauna includes *Icriodus symmetricus*, *Pol. decorosus*, *Pol. foliatus*, *Pol. pennatus*, and *Pol. dengleri*. As noted above, the overlap in the ranges of *A. rotundiloba* and *Pol. dengleri* is diagnostic for the upper part of the Lower *Pol. asymmetricus* Zone.

The conodont sequence at Trevone Bay and Marble Cliff corresponds closely with the sequence in the lower and upper parts of Ziegler's (1966*b*) sections in the Rheinisches Schiefergebirge, especially the Koppen section where the *Pol. varcus* and *S. hermanni–Pol. cristatus* Zones and the entire Lower *Pol. asymmetricus* Zone are represented. *Pol. beckmanni* was not recovered from the Trevose Slates and the Marble Cliff faunas do not include *Pol. caelata*, *Pol. ordinata*, *Spathognathodus sannemanni*, and *Schmidtognathus pietzneri*, among others, but considering the comparative poverty of the Cornish faunas, these absentees do not greatly detract from the overall similarity of fauna and faunal sequence. Because the fauna of the *S. hermanni–Pol. cristatus* Zone was not recovered the Middle/Upper Devonian boundary of the conodont zonation cannot be precisely placed. However, it must roughly correspond to the boundary between the Trevose Slates and the Marble Cliff Beds, that is, within the series of altered rocks associated with the dolerite sill north of Trevone Bay and on the Trevose Peninsula.

Although the bulk of the bioclastic material in the limestones is believed to be turbiditic in origin, there is no evidence to suggest that any elements of the conodont fauna were derived. However, the uneven distribution of species and the preponderance of broken elements would seem to be the result of sorting and current reworking. The few unusually productive horizons (for example Sample 17) are interpreted as lag deposits in which large, robust, or structurally stable elements were relatively concentrated, such as *Icriodus*, *Ancyrodella* and some of the lancet-shaped species of *Polygnathus*. In this respect the fauna of Sample 17 resembles two assemblages Krebs and Ziegler (1966) recovered from detrital reef limestones (lowermost Grenzschiefer) near the Middle/Upper Devonian boundary in the vicinity of Aachen, Germany. Sorting may also account for the absence of the more delicate broad platform elements, such as *Pol. asymmetricus* and *Palmatolepis*, in samples where they would normally be expected to occur. Thus in cases where the differentiation of adjoining zones or parts of a single zone depends on the ranges of a few diagnostic species that are not closely related and of contrasting morphologies and hydrodynamic property, the precision of correlation of even the furthest offshore facies may be effected by sorting. The collection of large samples from widely spaced points along a horizon will tend to minimize the effect of sorting, but in sections like the Marble Cliff this is not usually possible.



TEXT-FIG. 3. Stratigraphic succession at Marble Cliff showing sample-horizons.

SYSTEMATIC DESCRIPTIONS

The fossils described are deposited in the Sedgwick Museum, Cambridge, where they are numbered SM H9330–H9379. Other material is in the palaeontology collections of the Department of Geology, University of Hull, England.

Ancyrodella rotundiloba (Bryant)

Plate 65, figs. 5, 6, 8, 9

1879 *Polygnathus tuberculatus* Hinde, p. 366, pl. 17, fig. 10 [*non* fig. 9 = lectotype of *Pol. tuberculatus* selected by Bryant (1921, p. 25)].
1921 *Pol. rotundilobus* Bryant, pp. 26, 27, pl. 12, figs. 1–6; text-fig. 7.
1941 *Ancyrodella rotundiloba* (Bryant); Branson and Mehl, p. 202.
1957 *A. rotundiloba* (Bryant); Bischoff and Ziegler, p. 42, pl. 16, figs. 5–12, 14–17.
1958 *A. rotundiloba* (Bryant); Ziegler, pp. 44–5, pl. 11, figs. 11, 12.
1966 *A. rotundiloba rotundiloba* (Bryant); Krebs and Ziegler, pl. 1, figs. 10–13, 15–16.
1966 *A. rotundiloba* (Bryant) n. subsp.; Krebs and Ziegler, pl. 1, figs. 6–9.
1966 *A. rotundiloba rotundiloba* (Bryant); Glenister and Klapper, p. 799, pl. 85, figs. 9–13.
1967 *A. rotundiloba* (Bryant); Müller and Clark, p. 908, pl. 115, fig. 8; pl. 116, figs. 1–5; text-figs. 5, 6.

Material. Eight specimens; SM H9330–H9334.

Remarks. Müller and Clark (1967) have determined the ontogeny and extremes of variation in *A. rotundiloba* from the Squaw Bay Limestone of Michigan. The specimens from the Longcarrow Cove Tuffs and Slates are all relatively early growth stages and compare well with the series c to h (text-fig. 6) in Müller and Clark's ontogenetic scheme.

The Cornish specimens are unusual in having only a few nodes on the upper surface, no secondary keels and an extremely large basal cavity (or pit). In this latter feature, the specimens are perhaps closest to the 'typical' examples of *A. rotundiloba* reported by Krebs and Ziegler (1966) from the Walheim section near Aachen, Germany, particularly the specimen figured by them as Plate 1, figs. 10–11; the two small specimens from the same fauna, figured as *A. rotundiloba* n. subsp. (Pl. 63, figs. 6–7, 8–9), are interpreted as early growth stages of *A. rotundiloba*.

Range. Upper part of the Lower *Pol. asymmetricus* Zone to top of the Middle *Pol. asymmetricus* Zone (Ziegler 1962*b*, pp. 17, 19), corresponding to the Upper Devonian *Pharciceras lunulicosta* Zone (Iα) (Krebs and Ziegler 1966, pp. 748, 749). The entry of *A. rotundiloba* defines the base of the upper part of the Lower *Pol. asymmetricus* Zone. Sample-horizons 15–18, Longcarrow Cove Tuffs and Slates, Marble Cliff.

Palmatolepis transitans Müller

Plate 63, figs. 1, 8

1956 *Palmatolepis* (*Manticolepis*) *transitans* Müller, pp. 18, 19, pl. 1, figs. 1, 2.
1957 *Palmatolepis transitans* Müller; Bischoff and Ziegler, p. 81, pl. 16, figs. 24, 25 [*non* figs. 23, 26, 27 = *Polygnathus asymmetricus asymmetricus* Bischoff and Ziegler].
1958 *Palmatolepis transitans* Müller, Ziegler, p. 66, pl. 1, figs. 9, 11–13; pl. 2, figs. 1–3, 8.

Material. Five specimens; SM H9335, 6.

Remarks. SM H9336 (Pl. 61, fig. 8) differs from typical representatives of *Pal. transitans* in having no clearly differentiated outer lobe and an unusual large flaring basal cavity. This type of basal cavity is also seen in a specimen referred to *Pal. transitans* by Ziegler (1958, p. 2, fig. 2) and is the distinguishing character of *Palmatolepis*? *disparalvea* Orr and Klapper from the *S. hermanni–Pol. cristatus* Zone in Illinois and New York. Ziegler's specimen is from the upper part of the Lower *Pol. asymmetricus* Zone at the Martenberg section, near Adorf, in the Rheinisches Schiefergebirge.

Although the specimen at hand lacks the usually well-defined outer lobe of *Pal. transitans*, it is tentatively assigned to the species because the basal cavity is posterior in

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EXPLANATION OF PLATE 63

Figs. 1, 8. *Palmatolepis transitans* Müller. 1*a*, *b*, Upper and lower views, SM H9335, Sample 8, Marble Cliff Beds. 8*a*, *b*, Upper and lower views, SM H9336, Sample 8, Marble Cliff Beds.

Fig. 2. *Polygnathus dengleri* Bischoff and Ziegler. *a*, *b*, Upper and lower views, SM H9351, Sample 13, Marble Cliff Beds.

Figs. 3, 7, 10. *Pol. cristatus* (?) Hinde. Specimens are from the Marble Cliff Beds. 3*a*, *b*, Upper and lower views of early growth stage, SM H9339, Sample 8. 7*a*, *b*, Upper and lower views, SM H9340, Sample 1. 10, Upper view, SM H9341, Sample 2.

Fig. 4. *Pol. cf. Pol. rugosus* Huddle. *a*, *b*, Upper and lower views, SM H9365, Sample 17, Longcarrow Cove Tuffs and Slates.

Fig. 5. *Pol. decorosus* Stauffer *s.l.* Lower view of early growth stage with large, flaring basal cavity, illustrating transition to *Schmidtognathus* Ziegler, SM H9342, Sample 8, Marble Cliff Beds.

Fig. 6. *Pol. linguiformis* Hinde. *a*, *b*, Upper and lower views of fragment, SM H9357, Sample 15, Longcarrow Cove Tuffs and Slates.

Fig. 9. *Pol. asymmetricus asymmetricus* Bischoff and Ziegler. *a*, *b*, Upper and lower views, SM H9337, Sample 1, Marble Cliff Beds.

All magnifications $\times 50$.

position, the carina is only slightly curved, and it has an azygous node. It is similar in form to *Pol. asymmetricus asymmetricus* Bischoff and Ziegler, but in that subspecies the basal cavity is anterior (or in some cases central) in position and the azygous node is weakly defined or absent.

The posterior position of the basal cavity in the earliest species of *Palmatolepis* appears to be a more diagnostic character than the degree of development of the outer lobe and asygous node for differentiating the genus from closely related species of *Polygnathus*. In *Pol. asymmetricus* and *Pol. cristatus* the basal cavity is usually anterior or, more rarely, central in position. If one follows Ziegler's (1962*a*, 1966*b*) phylogenetic scheme along the line from variants of *Pol. decorosus* Stauffer *s.l.* to the *Pol. cristatus* group to *Pol. asymmetricus ovalis*, *Pol. asymmetricus asymmetricus*, and finally to *Palmatolepis*, the basal cavity shows a tendency to migrate from an anterior to central position in *Polygnathus* to a posterior position in *Palmatolepis*. There is also a parallel tendency towards a reduction in the size of the basal cavity, so that in possessing the large flaring basal cavity *Palmatolepis*? *disparalvea* and the two specimens discussed above deviate from the main evolutionary line in *Palmatolepis* which leads to *Palmatolepis punctata* Ulrich and Bassler. *Palmatolepis*? *disparalvea* belongs in *Palmatolepis* and is distinguished from *Pal. transitans s.s.* by its strongly differentiated outer lobe and much coarser ornamentation.

Range. Base of Lower *Pol. asymmetricus* Zone to upper part of the *Ancyrognathus triangularis* Zone (Ziegler 1962*b*, pp. 17, 20). Sample-horizons 1–9, Marble Cliff Beds, Marble Cliff.

Polygnathus asymmetricus ovalis Ziegler and Klapper

1957 *Polygnathus dubia dubia* Hinde; Bischoff and Ziegler, p. 88, pl. 16, fig. 19; pl. 21, figs. 1, 2.
1958 *Pol. dubia dubia* Hinde; Ziegler, pp. 57, 58, pl. 1, figs. 1–3, 7.
1964 *Pol. asymmetrica ovalis* Ziegler and Klapper; Ziegler, Klapper, and Lindström, pp. 422, 423.
1966 *Pol. asymmetrica ovalis* Ziegler and Klapper; Ziegler 1966*b*, p. 671, pl. 5, fig. 6.
1966 *Pol. asymmetrica ovalis* Ziegler and Klapper; Glenister and Klapper, p. 828, pl. 87, figs. 8–9.
1967 *Pol. dubius* Hinde; Müller and Clark, p. 916, pl. 115, figs. 5, 6.

Material. Five specimens.

Range. Base of Lower *Pol. asymmetricus* Zone into Upper *Pol. asymmetricus* Zone (Ziegler 1962*b*, table 2). Sample-horizons 1–8, Marble Cliff Beds, Marble Cliff.

Polygnathus asymmetricus asymmetricus Bischoff and Ziegler

Plate 63, fig. 9

1957 *Polygnathus dubia asymmetrica* Bischoff and Ziegler, pp. 88, 89, pl. 16, figs. 18, 20–2; pl. 21, fig. 3.
1958 *Pol. dubia asymmetrica* Bischoff and Ziegler; Ziegler, pp. 57, 58, pl. 1, figs. 4–6, 8, 10.
1964 *Pol. asymmetrica asymmetrica* Bischoff and Ziegler; Ziegler and Klapper in Ziegler, Klapper, and Lindström, p. 423.
1966 *Pol. asymmetrica* Ziegler, 1966*b*, pl. 5, figs. 9, 10.

Material. Eighteen specimens; SM H9337, H9338.

Remarks. According to Ziegler (1962*a*, 1966*b*) *Pol. asymmetricus ovalis* is the stem form of the lineage that gave rise to *Palmatolepis* during the early part of the Late Devonian. The important trends were (1) an increase in platform asymmetry by expansion of the outer side to form a lobe, (2) the development of an azygous node, (3) a reduction in the size of the basal cavity, and (4) migration of the basal cavity to a posterior position on the platform. The last mentioned is here regarded as the most diagnostic feature for differentiating *Palmatolepis* from closely related species of *Polygnathus*. *Pal. transitans* is most closely related to *Pol. asymmetricus asymmetricus*. In *Pol. asymmetricus asymmetricus* the outer side has not developed into a lobe, an azygous node is either missing or weakly developed and the basal cavity is in the centre or anterior part of the platform.

Range. Base to top of *Pol. asymmetricus* Zone (Ziegler 1962*b*, table 2). Sample-horizons 1–8 Marble Cliff Beds, Marble Cliff.

Polygnathus cristatus (?) Hinde

Plate 63, figs. 3, 7, 10

[?] 1879 *Polygnathus cristatus* Hinde, p. 366, pl. 17, fig. 11.
[?] 1921 *Pol. cristatus* Hinde; Bryant, p. 24.
[?] 1933 *Pol. cristata* Hinde; Branson and Mehl 1933*a*, p. 147, pl. 11, fig. 10 [the holotype].
1957 *Pol. cristata* Hinde; Bischoff and Ziegler, pp. 86, 87, pl. 15, figs. 1–7, 10 [*non* figs. 8–9, 11–13, 16 = *Pol. asymmetricus asymmetricus* Bischoff and Ziegler]; pl. 17, figs. 12, 13.
1964 *Pol. cristata* Hinde; Orr, pp. 13, 14, pl. 3, figs. 4–8, 10; text-fig. 4.
1966 *Pol. cristata* Hinde; Ziegler 1966*b*, pp. 670, 671, pl. 4, figs. 17, 18, 19–21 [?], 22, 23; pl. 5, figs. 1, 2, 3–4 [?], 5.
1968 *Pol. cristatus* Hinde; Orr and Klapper, pl. 139, figs. 1–4, 8, 9.

Material. Thirty specimens; SM H9339–H9341.

Diagnosis. The platform is broad and oval-shaped (symmetrical) in outline, with a flattened anterior and pointed posterior margins. The coarse ornamentation on the upper surface is distinctive; rows of discrete rounded nodes are aligned roughly parallel to a gently curved median carina of similar but larger nodes. In late growth stages, the more median rows tend to diverge from the carina near the anterior end, producing furrows on both sides of the carina. The nodes are more irregularly arranged and more closely spaced in late growth stages. The lower surface has a median keel with a well-developed basal cavity located in the anteriormost third of the platform.

Remarks. The name *Pol. cristatus* Hinde rather loosely refers to broad platform conodonts similar to *Pol. asymmetricus ovalis* but which are thicker and more coarsely ornamented. Bischoff and Ziegler (1957) and Ziegler (1966*b*) interpreted *Pol. cristatus* as a highly variable species. They included in the species forms with rather pointed anterior platform margins and more centrally located basal cavities, as well as large forms with relatively small densely packed nodes on the upper surface that are fused into irregular networks or ramifying ridges. These variants were not found in the Marble Cliff Beds. The Marble Cliff specimens are remarkably similar to the specimens figured by Orr (1964) from the *S. hermanni–Pol. cristatus* Zone in the Alto Formation of Southern Illinois.

The assignment of the specimens to *Pol. cristatus* Hinde is questioned because the generally held concept of the species, which focuses on *Pol. cristatus* Hinde *sensu*

Bischoff and Ziegler, is not in accord with Hinde's holotype (British Museum (N.H.) A4319), from the 'Conodont-bed' (= North Evans Limestone) on Eighteenmile Creek, North Evans, New York. In this specimen, which only shows the upper side, the rows of nodes converge posteriorly, and the outermost row parallels the platform margin; also, some of the anterior nodes are clearly fused into ridges. Anteriorly the rows of nodes diverge from the carina to such a degree that the anterior end of the platform appears divided into lobes. These features, which are not seen in the hypotypes or the specimens at hand, are more characteristic of *Ancyrodella* than *Polygnathus*.

Range. *Pol. cristatus* Hinde *sensu* Bischoff and Ziegler ranges from within the *S. hermanni–Pol. cristatus* Zone (Ziegler 1966*b*, p. 675) to the top of the Lower *Pol. asymmetricus* Zone (Bischoff and Ziegler 1957, table 4; Ziegler 1962*b*, p. 19). Sample-horizons 1–8, Marble Cliff Beds, Marble Cliff.

Polygnathus decorosus Stauffer *s.l.*

Plate 63, fig. 5; Plate 64, figs. 1–8

1938 *Polygnathus decorosus* Stauffer, p. 438, pl. 53, figs. 1, 5, 6, 10, 11, 15, 16, 20, 30.
1957 *Pol. foliata* Bryant; Müller and Müller, pp. 1086, 1087, pl. 135, fig. 1.
1957 *Pol. decorosa* Stauffer; Bischoff and Ziegler, p. 87.
1957 *Pol. xyla* Stauffer; Bischoff and Ziegler, p. 101, pl. 5, figs. 11–17.
1964 *Pol. decorosa* Stauffer; Orr, pp. 14, 16, pl. 1, figs. 3, 5, 7; pl. 3, fig. 2.
1966 *Pol. decorosa* Stauffer *s.l.*; Ziegler 1966*b*, pl. 3, figs. 1–4; pl. 4, figs. 1–4; pl. 6, figs. 7–17.
1966 *Pol. xyla* Stauffer; Wittekindt, p. 642, pl. 3, figs. 18, 19.
1966 *Pol. decorosus* Stauffer; Anderson, p. 411, pl. 50, figs. 6–8, 10, 11, 15, 19.
1967 *Pol. foliata* Bryant; Clark and Ethington, p. 61, pl. 7, fig. 7 [*non* pl. 5, fig. 7 = *Pol. foliatus* Bryant].
1967 *Pol. normalis* Miller and Youngquist; Clark and Ethington, p. 63, pl. 4, fig. 3 [*non* pl. 5, fig. 10 = *Pol. foliatus* [?] Bryant].
1967 *Pol. foliatus* Bryant; Müller and Clark, p. 916, pl. 115, fig. 4.

Material. 185 specimens; SM H9342–H9350.

Diagnosis. *Polygnathus decorosus* Stauffer *s.l.* is a morphologically simple polygnathid with a narrow lanceolate platform and relatively long free blade. The unit is moderately to strongly bowed and arched. The ornamentation is weakly developed and consists of nodes or transverse ridges along the platform margins. The free blade is usually uniform in height and carries numerous teeth of nearly equal size and height. In early growth stages (Pl. 64, figs. 1, 2, 7, 8) the platform is symmetrical in outline (the lateral margins are nearly parallel), shorter than the free blade, and the relatively large basal cavity is situated at the point where the free blade joins the platform. In late growth stages (Pl. 64, figs. 3–6) the platform is more asymmetrical, about as long as the free blade, and the basal cavity is less conspicuous and lies posterior of the join between the free blade and the platform.

Remarks. *Pol. decorosus s.l.* is the most common conodont in the faunas from the Marble Cliff. It is an extremely variable species (Ziegler 1966*b*) and many of the Cornish specimens show gradations toward *Pol. foliatus* Bryant and *Pol. pennatus* Hinde and related species. Müller and Müller (1957) regarded *Pol. decorosus* as a synonym of *Pol. foliatus* Bryant. However, in late growth stages of *Pol. foliatus* the platform is broader and distinctly asymmetrical, the ornamentation on the posterior half consists of numerous small nodes (Bryant 1921, p. 24; Huddle 1934, p. 99), and the teeth on the free blade increase in height anteriorly.

Ziegler (1966*b*) interprets *Pol. decorosus s.l.* as a stem form from which several new species and one genus evolved during late Middle and early Late Devonian time. These forms include: *Pol. varcus* (reduced platform, long free blade), *Pol. foliatus* and *Pol. normalis* Miller and Youngquist (broad, asymmetrical platforms with noded or ribbed ornamentation), *Pol. pennatus* (coarse radially ribbed ornamentation), *Pol. cristatus* group (broad, symmetrical platforms with coarse nodes) and *Schmidtognathus* (large, asymmetrical basal cavity). Compared to *Pol. decorosus s.l.*, these forms also tend to have more highly developed free blades with teeth of varying size and height and well-defined crimps.

Range. Because of the present taxonomic tangle that surrounds *Pol. decorosus* and closely related species (*Pol. foliatus*, *Pol. normalis*, *Pol. pennatus*, among others) and because of their relatively long ranges, these common lanceolate polygnathids have limited biostratigraphic value. *Pol. decorosus s.l.* apparently ranges from the lower Middle Devonian (Wittekindt 1966, table 1) into the upper part of the Upper Devonian (Famennian) (Ziegler 1966*b*, text-fig. 4). Sample-horizons 31, Trevose Slates, Trevone Bay; 33, Trevose Slates, Rock; 1–13, Marble Cliff Beds; and 17, 18, Longcarrow Cove Tuffs and Slates, Marble Cliff.

Polygnathus dengleri Bischoff and Ziegler

Plate 63, fig. 2; Plate 64, fig. 4; Plate 66, fig. 2

1957 *Polygnathus dengleri* Bischoff and Ziegler, pp. 87, 88, pl. 15, figs. 14, 15, 17–24; pl. 16, figs. 1–4.

1966 *Pol. dengleri* Bischoff and Ziegler; Ziegler 1966*b*, pp. 671, 673, pl. 6, figs. 1–6.

1967 *Pol. dengleri* Bischoff and Ziegler; Müller and Clark, p. 916, pl. 115, figs. 3, 7.

Material. Ten specimens; SM H9351–H9353.

Diagnosis. The platform is narrow, oval-shaped, and symmetrical in outline, with a pointed posterior margin. The free blade is short and high. The ornamentation on the flat upper surface consists of weakly developed short transverse ridges along the platform margin; the ridges do not extend into the smooth weakly developed troughs that parallel the median carina.

EXPLANATION OF PLATE 64

Figs. 1–8. *Pol. decorosus* Stauffer *s.l.* 1*a*, *b*, *c*, Upper, lower, and lateral views of early growth stage, SM H9343, Sample 8, Marble Cliff Beds. 2*a*, *b*, *c*, Upper, lower, and lateral views of early growth stage, SM H9344, Sample 8, Marble Cliff Beds. 3, Oblique view of specimen transitional to *Pol. pennatus* Hinde, SM H9345, Sample 8, Marble Cliff Beds. 4, Upper view of late growth stage, SM H9346, Sample 17, Longcarrow Cove Tuffs and Slates. 5*a*, *b*, *c*, Upper, lower, and lateral views of late growth stage, SM H9347, Sample 17, Longcarrow Cove Tuffs and Slates. 6*a*, *b*, *c*, Upper, lower, and lateral view of late growth stage, SM H9348, Sample 17, Longcarrow Cove Tuffs and Slates. 7*a*, *b*, *c*, Upper, lower, and lateral views of early growth stage, SM H9349, Sample 8, Marble Cliff Beds. 8*a*, *b*, *c*, Upper, lower, and lateral views of early growth stage, SM H9350, Sample 8, Marble Cliff Beds.

Fig. 9. *Pol. linguiformis* Hinde. Upper view, SM H9358, Sample 17, Longcarrow Cove Tuffs and Slates.

All magnifications ×50.

SERIES	MIDDLE DEVONIAN			UPPER DEVONIAN?														UPPER DEVONIAN						
STAGE	GIVETIAN																	FRASNIAN						
Ammonoid Zone	*M. terebratum*																	*P. lunulicosta* (Ia)						
Conodont Zone	*Pol. varcus*			Lower *Pol. asymmetricus* – lower part														Lower *Pol. asymmetricus* – upper part						
Conodont species / Sample	TREVOSE SLATES			MARBLE CLIFF BEDS														LONGCARROW CV. TUFFS & SLATES						
	30	31	33	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
Polygnathus varcus Stauffer	3	17	1						1		1					1								24
Pol. linguiformis Hinde	6	36	8			1					1							1		1				54
Pol. spp.	1		4	17	1	2		1	8	1	11		9	1	12	13	6	1		29	1	3		121
Neoprioneodus alatus (Hinde)	1								1			1			1					1				5
Hindeodella spp.	7	1		1	1				2		3				1			1		2	4			23
Roundya spp.	1								1			1												3
Schmidtognathus hermanni Ziegler		1											1?											2
Pol. decorosus Stauffer *s.l.*		3	2	8	2	16		1	34	1	58		8	1	10	14				22	5			185
N. pronus (Huddle)		2		1					3		1							1		1				9
Icriodus symmetricus Branson & Mehl		2																		2				4
Ozarkodina spp.		2		2		2			2		1									3	1			13
Bryantodus spp.		1				1			4		2	2			3	1				4				18
Pol. asymmetricus ovalis Ziegler & Klapper				1					1		3													5
Pol. asymmetricus asymmetricus Bischoff & Ziegler				1		4		3	6	1	3													18
S. wittekindti Ziegler				3			1		1		1				1									7
Pol. cristatus [?] Hinde				6	1	4		1	3	3	12													30
Palmatolepis transitans Müller				1	1						2	1												5
Pol. foliatus Bryant				1				1	3	1	2									7				15
Ligonodina spp.				1		1				1	1							1		4				9
Pol. variabilis Bischoff & Ziegler						1						1												2
S. peracutus (Bryant)									1															1
Pol. bryanti Huddle									2															2
Pol. pennatus Hinde									1		1				1?			1?		4				8
Trichonodella sp.									1															1
B. grandis Bischoff & Ziegler									1															1
Spathognathodus brevis Bischoff & Ziegler											1													1
B. pravus (Bryant)											1													1
Pol. dengleri Bischoff & Ziegler											5					2		1		2				10
Lonchodina sp.											2													2
B. biculminatus Bischoff & Ziegler											1									1				2
Lonchodina discreta Ulrich & Bassler													1											1
Pol. sp. Ziegler													1				1			1				3
Angulodus sp.													1											1
Ancyrodella rotundiloba (Bryant)																		3		4	1?			8
Pol. subserratus Branson & Mehl																				1				1
Pol. cf. *Pol. rugosus* Huddle																				2				2
Icriodus spp.																				4				4
O. immersa [?] (Hinde)																				1				1
Indeterminate fragments	6	12		4	1	21	2	25	32	2	13	17	7	4	11	19		2		24	28			
Totals	25	77	15	47	7	53	3	32	108	10	126	23	28	6	40	50	7	12	0	120	40	3	0	
Sample wt. (kg.)	.5	.5	.5	1.0	.5	1.0	.5	.5	1.5	.5	1.5	.5	1.5	1.5	1.5	1.0	.5	1.0	.5	1.5	1.0	.5	.5	

TEXT-FIG. 4. Distribution of conodonts in samples from Trevone Bay, Rock, and Marble Cliff.

Remarks. The specimens are early growth stages and compare most closely with specimens of *Pol. dengleri* figured by Ziegler (1966*b*).

Range. *Pol. dengleri* enters somewhat above the base of the Lower *Pol. asymmetricus* Zone (Ziegler 1966*b*, tables) and ranges to the top of the zone (Bischoff and Ziegler 1957, table 4; Ziegler 1958, tables 2, 10; Ziegler 1962*b*, p. 17). Sample-horizons 8–13, Marble Cliff Beds, and 15–17, Longcarrow Cove Tuffs and Slates, Marble Cliff.

Polygnathus foliatus Bryant

Plate 65, figs. 1, 2

1921 *Polygnathus foliatus* Bryant, p. 24, pl. 10, figs. 13–16.
1934 *Pol. foliata* Bryant; Huddle, p. 99, pl. 8, figs. 14–17.

[*non*] 1957 *Pol. foliata* Bryant; Bischoff and Ziegler, p. 90, pl. 4, figs. 1–4 [= *Polygnathus* sp. ?]
[*non*] 1957 *Pol. foliata* Bryant; Müller and Müller, pp. 1086, 1087, pl. 135, fig. 1 [= *Pol. decorosus* Stauffer *s.l.*].
1967 *Pol. foliata* Bryant; Clark and Ethington, p. 61, pl. 5, fig. 7 [*non* pl. 7, fig. 7 = *Pol. decorosus* Stauffer *s.l.*].

Material. Fifteen specimens; SM H9354–H9356.

Remarks. See *Polygnathus decorosus* Stauffer *s.l.*

Range. Sample-horizons 1–8, Marble Cliff Beds, and 17, Longcarrow Cove Tuffs and Slates, Marble Cliff.

Polygnathus linguiformis Hinde

Plate 63, fig. 6; Plate 64, fig. 9; Plate 66, fig. 4

1879 *Polygnathus linguiformis* Hinde, p. 367, pl. 17, fig. 15.
1921 *Pol. linguiformis* Hinde; Bryant, p. 25, pl. 11, figs. 1–9; pl. 14, fig. 2.

EXPLANATION OF PLATE 65

Figs. 1–2. *Polygnathus foliatus* Bryant. 1*a*, *b*, Upper and lower views, SM H9354, Sample 17, Longcarrow Cove Tuffs and Slates. 2*a*, *b*, Upper and lower views, SM H9355, Sample 17, Longcarrow Cove Tuffs and Slates.

Figs. 3, 7. *Schmidtognathus wittekindti* Ziegler. 3*a*, *b*, *c*, Upper, lower, and lateral views of early growth stage, SM H9369, Sample 12, Marble Cliff Beds. 7*a*, *b*, Upper and lower views of late growth stage, SM H9370, Sample 1, Marble Cliff Beds.

Fig. 4. *Pol. dengleri* Bischoff and Ziegler. *a*, *b*, Upper and lower views, SM H9352, Sample 8, Marble Cliff Beds.

Figs. 5, 6, 8, 9. *Ancyrodella rotundiloba* (Bryant). Specimens are from the Longcarrow Cove Tuffs and Slates. 5, Upper view of early growth stage, SM H9330, Sample 17. 6*a*, *b*, Upper and lower views, SM H9331, Sample 15. 8*a*, *b*, Upper and lower views, SM H9332, Sample 15. 9*a*, *b*, Upper and lower views of early growth stage, SM H9334, Sample 17.

All magnifications ×50.

EXPLANATION OF PLATE 66

Fig. 1. *Schmidtognathus hermanni* Ziegler. *a*, *b*, *c*, Upper, lower, and lateral views of early growth stage, SM H9368, Sample 31, Trevose Slates, Trevone Bay.

Fig. 2. *Pol. dengleri* Bischoff and Ziegler. *a*, *b*, Upper and lower views, SM H9353, Sample 8, Marble Cliff Beds.

Fig. 3. *Icriodus symmetricus* Branson and Mehl. Upper view, SM H9374, Sample 31, Trevose States, Trevone Bay.

Fig. 4. *Pol. linguiformis* Hinde. *a*, *b*, Upper and lower views, SM H9359, Sample 31, Trevose Slates, Trevone Bay.

Figs. 5, 8. *Bryantodus biculminatus* Bischoff and Ziegler. 5, Lateral view, SM H9371, Sample 8, Marble Cliff Beds. 8, Lateral view, SM H9372, Sample 17, Longcarrow Cove Tuffs and Slates.

Fig. 6. *Hindeodella* sp. Lateral view, SM H9373, Sample 8, Marble Cliff Beds.

Fig. 7. *Neoprioniodus pronus* (Huddle). Lateral view, SM H9376, Sample 8, Marble Cliff Beds.

Figs. 9–11. *Pol. varcus* Stauffer. Specimens are from the Trevose Slates, Trevone Bay. 9*a*, *b*, Upper and lower views, SM H9362, Sample 31. 10*a*, *b*, *c*, Upper, lower, and lateral views, SM H9363, Sample 30. 11*a*, *b*, Upper and lower views, SM H9364, Sample 31.

Fig. 12. *Ozarkodina immersa* [?] (Hinde). Lateral view, SM H9377, Sample 17, Longcarrow Cove Tuffs and Slates.

Fig. 13. *N. alatus* (Hinde). Lateral view, SM H9375, Sample 12, Marble Cliff Beds.

All magnifications ×50.

1957 *Pol. linguiformis* Hinde; Rhodes and Dineley, pp. 365, 366, pl. 37, figs. 17–19, 21; pl. 38, fig. 3.
1957 *Pol. linguiformis* Hinde; Bischoff and Ziegler, pp. 92, 93, pl. 1, figs. 1–13; pl. 16, figs. 30–5; pl. 17, figs. 1–8; pl. 19, fig. 18.
1966 *Pol. linguiformis* Hinde; Ziegler 1966*a*, pl. 1, figs. 7–10.
1966 *Pol. linguiformis linguiformis* Hinde; Wittekindt, pp. 635, 636, pl. 2, figs. 10–12.

Material. Fifty-four specimens; SM H9357–H9361.

Remarks. Polygnathus linguiformis Hinde is common and well preserved in the Trevose Slate faunas and comparatively rare in faunas from the Marble Cliff Beds and the Longcarrow Cove Tuffs and Slates. Specimens from the Trevose Slates show extreme ranges in size and in the coarseness of ornamentation. Two of the largest forms (late growth stages) from Sample 31 have two diagonal rows of nodes in the anterior part of the platform, which is a diagnostic feature of *Pol. linguiformis transversus* Wittekindt. However, the two specimens have much more weakly developed ridges than in *Pol. linguiformis transversus* and in all other features they are closest to *Pol. linguiformis* Hinde.

Range. Lower Devonian (Bischoff and Ziegler 1957, p. 93) to top of Upper *Pol. asymmetricus* Zone, (Ziegler 1962*b*, p. 19). Sample-horizons 30, 31, Trevose Slates, Trevone Bay; 33, Trevose Slates, Rock; 3–8, Marble Cliff Beds; and 15–17, Longcarrow Cove Tuffs and Slates, Marble Cliff.

Polygnathus varcus Stauffer

Plate 66, figs. 9–11

1940 *Polygnathus varcus* Stauffer, p. 430, pl. 60, figs. 49, 53, 55.
1940 *Pol. xylus* Stauffer, pp. 430, 431, pl. 60, figs. 42, 50, 54, 65–7, 69, 72–4, 78, 79.
1957 *Pol. varca* Stauffer; Rhodes and Dineley, p. 366, pl. 37, figs. 22, 23; pl. 38, fig. 7.
1957 *Pol. varca* Stauffer; Bischoff and Ziegler, pp. 98, 99, pl. 18, figs. 32–5; pl. 19, figs. 7–9.
[*non*] 1957 *Pol. xyla* Stauffer; Bischoff and Ziegler, p. 101, pl. 5, figs. 11–17 [= *Pol. decorosus* Stauffer *s.l.*].
1966 *Pol. varca* Stauffer; Ziegler 1966*a*, pl. 1, fig. 6.
1966 *Pol. varca* Stauffer; Wittekindt, pp. 639, 640, pl. 3, figs. 5–10.
[*non*] 1966 *Pol. xyla* Stauffer; Wittekindt, p. 642, pl. 3, figs. 18–19 [= *Pol. decorosus* Stauffer *s.l.*].
1966 *Pol. varca* Stauffer; Glenister and Klapper, pp. 830, 831, pl. 95, figs. 12–13 [*non* figs. 14, 15–16 = *Pol. decorosus* Stauffer *s.l.*].

Material. Twenty-four specimens; SM H9362–H9364.

Diagnosis. Pol. varcus has a short, narrow, weakly ornamented platform and an extraordinarily long free blade, up to twice as long as the platform. The ratio of platform length to free blade length appears to remain nearly constant through all growth stages. The sides of the platform are strongly folded upward, forming deep furrows on both sides of the median carina. The free blade is particularly distinctive; it is uniform in height and has a series of 10–20 teeth of variable size and shape but nearly equal height.

Remarks. All of the specimens at hand are intermediate and late growth stages, with markedly asymmetrical platform outlines. Anterior of the platform's midpoint, the margins abruptly constrict, especially on the outer side. The margin on the outer side then flares strongly outward, in a semicircular arc, and joins the free blade at a more anterior position than does the straighter inner margin. The posterior end of the platform is symmetrical and the margins converge uniformly to a point. In details of platform outline and in development of the free blade, the specimens at hand compare closely with specimens of *Pol. varcus* figured by Rhodes and Dineley (1957) from South Devon and by Bischoff and Ziegler (1957) and Ziegler (1966*a*) from the Rheinisches Schiefergebirge.

Specimens similar to *Pol. varcus* but with longer, more symmetrical and more highly ornamented platforms and shorter free blades with fewer teeth have been interpreted by Bischoff and Ziegler (1957) and Wittekindt (1966) as *Pol. xylus* Stauffer, a species which Glenister and Klapper (1966, p. 831) regard as a synonym of *Pol. varcus*. Forms of this type, for example the specimens figured herein as Plate 64, figs. 2, 7, and specimens of *Pol. varcus* figured by Glenister and Klapper (1966, pl. 95, figs. 14, 15–16) belong in *Pol. decorosus* Stauffer *s.l.* Glenister and Klapper (1966) suggested that in the ontogeny of *Pol. varcus* the length of the platform increases in proportion relative to the free blade and that the ornamentation becomes more highly developed. These changes are not seen in the Cornish specimens, even in the latest growth stages (Pl. 66, fig. 10), and it would seem that their analysis applies more closely to *Pol. decorosus* Stauffer *s.l.* rather than to *Pol. varcus*.

Range. *Pol. varcus* Zone (Bischoff and Ziegler 1957, p. 30) to top of Lower *Pol. asymmetricus* Zone (Ziegler 1962*b*, table 2). Sample-horizons 30–1, Trevose Slates, Trevone Bay; 33, Trevose Slates, Rock; 6–13, Marble Cliff Beds, Marble Cliff.

Schmidtognathus hermanni Ziegler

Plate 66, fig. 1

1966 *Schmidtognathus hermanni* Ziegler 1966*b*, pp. 664, 665, pl. 3, figs. 5–26.

Material. Two specimens; SM H9368.

Remarks. The figured specimen from the Trevose Slates (Sample 31) is an early growth stage and has the enlarged flaring basal cavity and narrow weakly ornamented platform of *Schmidtognathus hermanni*. *S. hermanni* developed from variants of *Pol. decorosus* Stauffer *s.l.* with enlarged basal cavities during the Late Middle Devonian; the link between these species is clearly seen in early growth stages (Ziegler 1966*b*, pl. 3, figs. 1–12).

Range. Base of *S. hermanni–Pol. cristatus* Zone into the lower part of the Lower *Pol. asymmetricus* Zone (Ziegler 1966*b*, p. 657). Ziegler (1966*b*, tables 1, 2, p. 659) also reports *S. hermanni* from the uppermost part of the *Pol. varcus* Zone. Sample horizons 31, Trevose Slates, Trevone Bay and 10, Marble Cliff Beds, Marble Cliff.

Schmidtognathus wittekindti Ziegler

Plate 65, figs. 3, 7

1966 *Schmidtognathus wittekindti* Ziegler 1966*b*, pp. 665, 666, pl. 1, figs. 11–16; pl. 2, figs. 1–10.

Material. Seven specimens; SM H9369–H9370.

Remarks. The specimens at hand are distinguished from a closely related species, *S. peracuta* (Bryant), by their narrower platform and very high free blade with the highest teeth in the middle.

Range. Upper part of the *S. hermanni–Pol. cristatus* Zone into the upper part of the Lower *Pol. asymmetricus* Zone (Ziegler 1966*b*, p. 666, text-fig. 2). Sample-horizons 1–12, Marble Cliff Beds, Marble Cliff.

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REFERENCES

ANDERSON, W. I. 1966. Upper Devonian conodonts and the Devonian-Mississippian boundary of north-central Iowa. *J. Paleont.* **40**, 395–415, pl. 48–52.

BISCHOFF, G. 1956. Oberdevonische Conodonten (to Iδ) aus dem Rheinischen Schiefergebirge. *Notizbl. hess. Landesamt. Bodenforsch.* **84**, 115–37, pl. 8–10.

—— and ZIEGLER, W. 1957. Die Conodontenchronologie des Mitteldevons und des tiefsten Oberdevons. *Abh. hess. Landesamt. Bodenforsch.* **22**, 1–136, pl. 1–21.

BRAITHWAITE, C. J. R. 1966. The petrology of Middle Devonian limestones in South Devon, England. *J. sedim. Petrol.* **36**, 176–92.

BRANSON, E. B. and MEHL, M. G. 1933*a*. A study of Hinde's types of conodonts preserved in the British Museum. *Univ. Mo. Stud.* **8**, 133–56, pl. 11–12.

—— —— 1933*b*. Conodonts from the Grassy Creek Shale of Missouri. Ibid. **8**, 171–259, pl. 13–21.

—— —— 1941. The recognition and interpretation of mixed conodont faunas. *Denison Univ., Bull., J. Sci. Lab.* **25**, 195–209.

BRYANT, W. L. 1921. The Genesee conodonts. *Buffalo Soc. Nat. Sci.* **13**, 1–59, pl. 1–16.

CLARK, D. L. and ETHINGTON, R. L. 1967. Conodonts and zonation of the Upper Devonian in the Great Basin. *Mem. geol. Soc. Am.* **103**, 1–94, pl. 1–9.

DEWEY, H. 1914. The geology of North Cornwall. *Proc. Geol. Ass., Lond.* **35**, 154–79.

DINELEY, D. L. 1961. The Devonian System in South Devonshire. *Fld Stud.* **1**, 121–40.

—— and RHODES, F. H. T. 1956. Conodont horizons in the west and south-west of England. *Geol. Mag.* **93**, 242–8.

ETHINGTON, R. L. 1965. Late Devonian and Early Mississippian conodonts from Arizona and New Mexico. *J. Paleont.* **39**, 566–89, pl. 67–8.

FOX, H. 1895. Notes on the cherts and associated rocks of Roundhole Point (Permizen Point), Cataclews Point, and Dinas Head, west of Padstow. *Trans. R. geol. Soc. Cornwall*, **11**, 687–724.

GAUSS, G. A. 1966. Some aspects of the slaty cleavage in the Padstow area of N. Cornwall. *Proc. Ussher Soc.* **1**, 221–4.

—— 1967. Structural aspects of the Padstow area, North Cornwall. Ibid. **1**, 284–5.

GLENISTER, B. F. and KLAPPER, G. 1966. Upper Devonian conodonts from the Canning Basin, Western Australia. *J. Paleont.* **40**, 777–842, pl. 85–96.

GOLDRING, R. and others. 1968. Devonian of southern Britain. *Int. Symp. Devonian System, Calgary*, **1**, 1–14.

HINDE, G. J. 1879. On conodonts from the Chazy and Cincinnati Group of the Cambro-Silurian, and from the Hamilton and Genesee-Shale divisions of the Devonian, in Canada and the United States. *Q. Jl geol. Soc. Lond.* **35**, 351–69, pl. 15–17.

HOUSE, M. R. 1956. Devonian goniatites from North Cornwall. *Geol. Mag.* **93**, 257–62.

—— 1961. The Devonian succession of the Padstow area, North Cornwall. *Abstr. Proc. Conf. Geol. Geomorph. SW Engld, 1960*, 4–5.

—— 1963. Devonian ammonoid successions and facies in Devon and Cornwall. *Q. Jl geol. Soc. Lond.* **119**, 1–27, pl. 1–4.

—— and SELWOOD, E. B. 1966. Palaeozoic palaeontology in Devon and Cornwall, in *Present views on some aspects of the geology of Cornwall and Devon*. Blackford, Truro, 45–86, pl. 1–4.

HUDDLE, J. W. 1934. Conodonts from the New Albany Shale of Indiana. *Bull. Am. Paleont.* **21**, 1–136, pl. 1–12.

KREBS, W. and ZIEGLER, W. 1966. Über die Mitteldevon/Oberdevon-Grenze in der Riffazies bei Aachen. *Fortschr. Geol. Rheinld Westf.* **9**, 731–54, pl. 1–2.

MATTHEWS, S. C. 1962. A Middle Devonian conodont fauna from the Tamar Valley. *Proc. Ussher Soc.* **1**, 27–8.

MÜLLER, K. J. 1956. Zur Kenntnis der Conodonten-Fauna des europäischen Devons, 1. Die Gattung *Palmatolepis*. *Abh. senckenb. naturforsch. Ges.* **494**, 1–70, pl. 1–11.

—— and CLARK, D. L. 1967. Early Late Devonian conodonts from the Squaw Bay Limestone in Michigan. *J. Paleont.* **41**, 902–19, pl. 115–18.

—— and MÜLLER, E. M. 1957. Early Upper Devonian (Independence) conodonts from Iowa, part I. Ibid. **31**, 1069–1108, pl. 135–42.

ORR, R. W. 1964. Conodonts from the Devonian Lingle and Alto Formations of southern Illinois. *Circ. Ill. St. geol. Surv.* **361**, 1–28, pl. 1–4.

—— and KLAPPER, G. 1968. Two new conodont species from Middle-Upper Devonian boundary beds of Indiana and New York. *J. Paleont.* **42**, 1066–75, pl. 139–40.

POLLOCK, C. A. 1968. Lower Upper Devonian conodonts from Alberta, Canada. Ibid. **42**, 415–43, pl. 61–4.

REID, C., BARROW, G. and DEWEY, H. 1910. The geology of the country around Padstow and Camelford. *Mem. geol. Surv. U.K.* 1–120.

RHODES, F. H. T. and DINELEY, D. L. 1957. Devonian conodont faunas from southwest England. *J. Paleont.* **31**, 353–69, pl. 37–8.

STAUFFER, C. R. 1938. Conodonts of the Olentangy Shale. Ibid. **12**, 411–43, pl. 48–53.

—— 1940. Conodonts from the Devonian and associated clays of Minnesota. Ibid. **14**, 417–35, pl. 58–60.

ULRICH, E. O. and BASSLER, R. S. 1926. A classification of tooth-like fossils, conodonts, with the descriptions of American Devonian and Mississippian species. *Proc. U.S. natn. Mus.* **68**, 1–63, pl. 1–11.

WEDEKIND, R. 1913. Die Goniatitenkalke des unteren Oberdevon von Martenberg bei Adorf. *Sber. Ges. naturf. Freunde Berl.* **1**, 23–77, pl. 4–7.

WITTEKINDT, H. 1966. Zur Conodontenchronologie des Mitteldevons. *Fortschr. Geol. Rheinld Westf.* **9**, 621–46, pl. 1–3.

ZIEGLER, W. 1958. Conodontenfeinstratigraphische Untersuchungen an der Grenze Mitteldevon/Oberdevon und in der Adorfstufe. *Notizbl. hess. Landesamt. Bodenforsch.* **87**, 7–77, pl. 1–12.

—— 1962*a*. Phylogenetische Entwicklung stratigraphisch wichtiger Conodonten-Gattungen in der *Manticoceras*-Stufe (Oberdevon, Deutschland). *Neues Jb. Geol. Paläont. Abh.* **114**, 142–68.

—— 1962*b*. Taxionomie und Phylogenie Oberdevonischer Conodonten und ihre stratigraphische Bedeutung. *Abh. hess. Landesamt. Bodenforsch.* **38**, 1–166, pl. 1–14.

—— 1966*a*. Zum höchsten Mitteldevon an der Nordflanke des Ebbesattels. *Fortschr. Geol. Rheinld Westf.* **9**, 519–38, pl. 1–2.

—— 1966*b*. Eine Verfeinerung der Conodontengliederung an der Grenze Mittel-/Oberdevon. Ibid. **9**, 647–76, pl. 1–6.

—— KLAPPER, G. and LINDSTRÖM, M. 1964. The validity of the name *Polygnathus* (Conodonta, Devonian and Lower Carboniferous). *J. Paleont.* **38**, 421–3.

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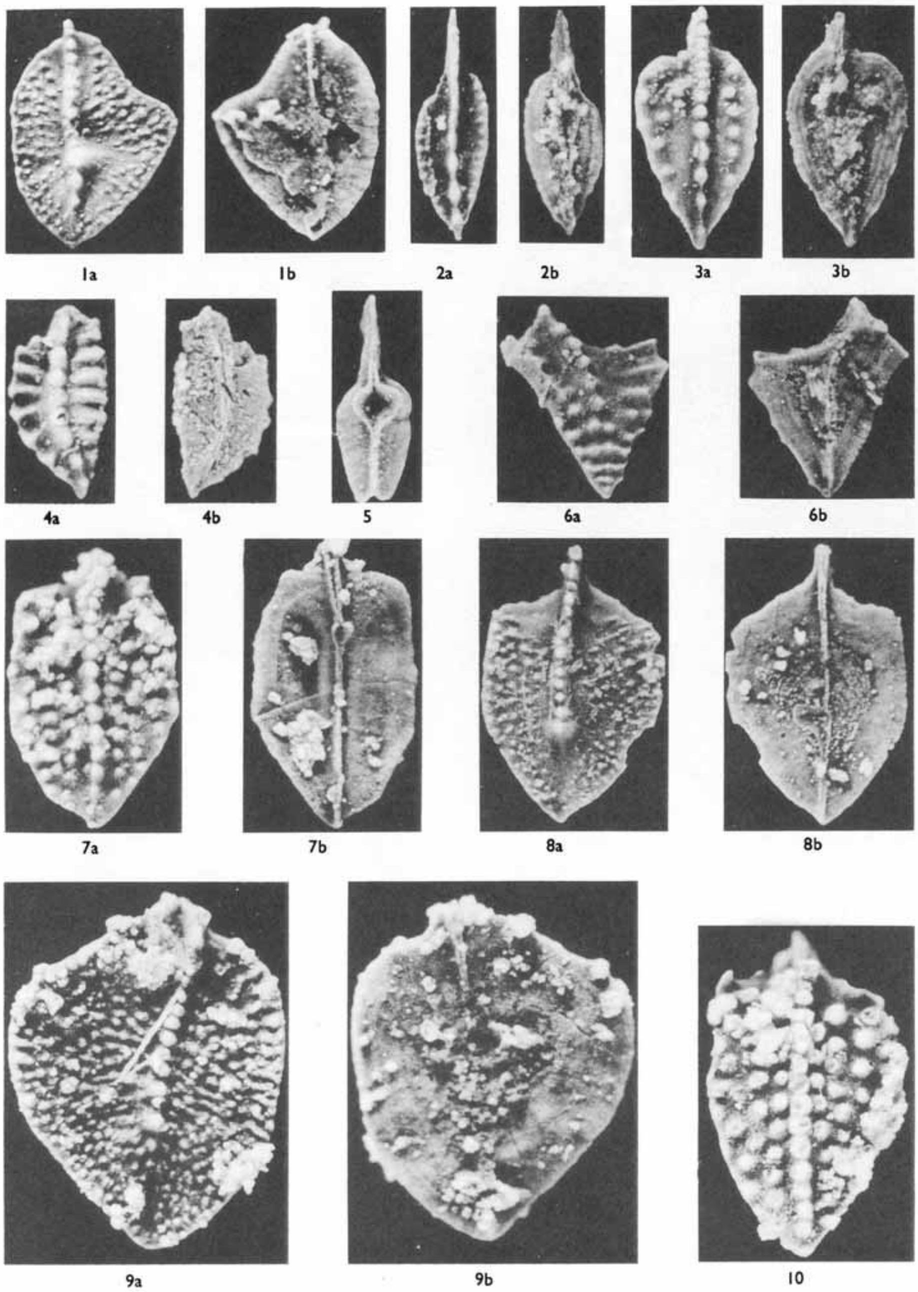
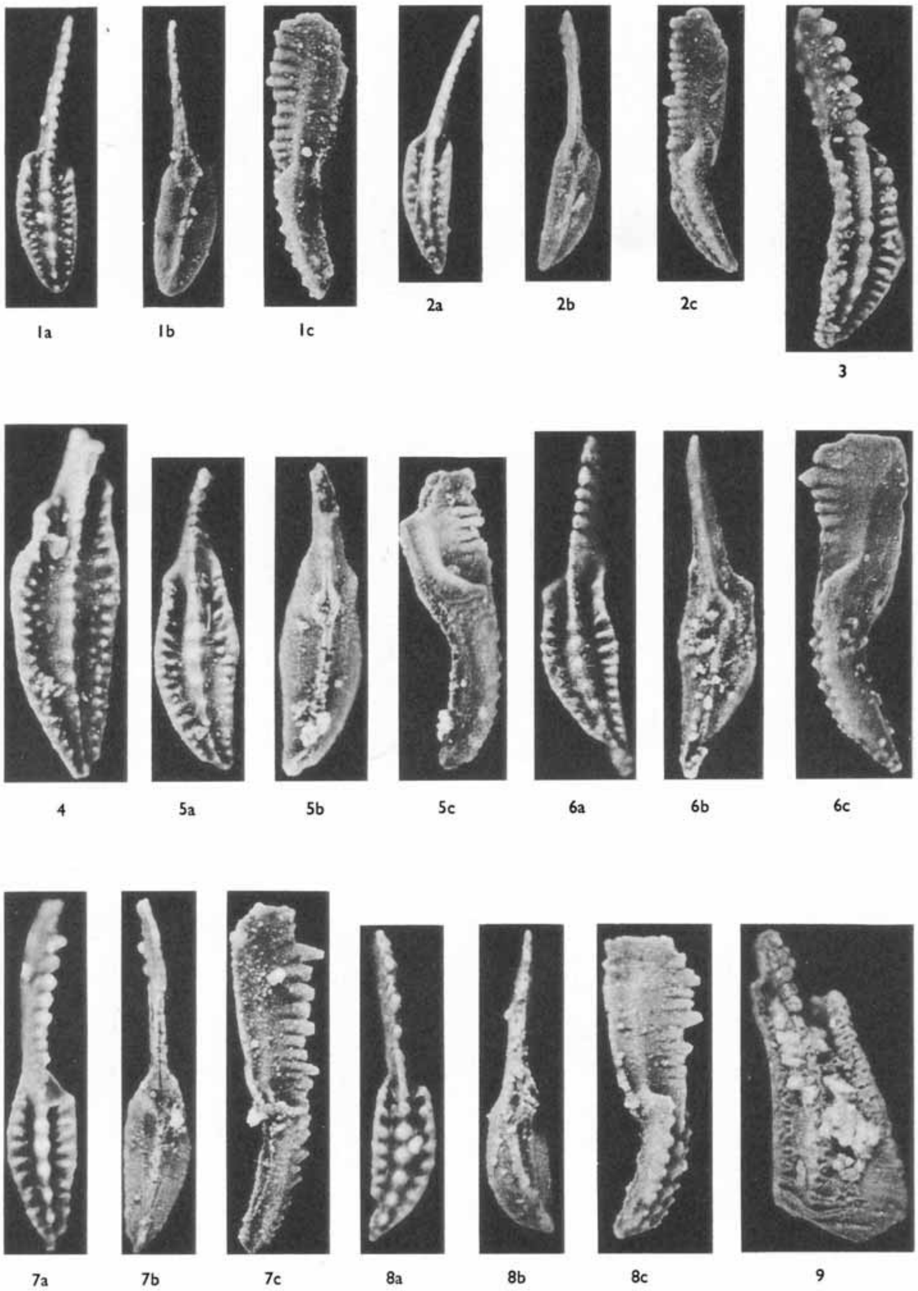
NOTE ADDED IN PROOF

Professor W. Ziegler has informed the writer that he has a paper in press with Dr. J. Kullmann on their restudy of the Martenberg section in which they demonstrate that the boundary between the *M. terebratum* and *P. lunulicosta* zones corresponds to the boundary between the lower and upper parts of the *S. hermanni–Pol. cristatus* Zone. This correlation places the succeeding lower part of the Lower *Pol. asymmetricus* Zone (and the Marble Cliff Beds) firmly in the Upper Devonian.



KIRCHGASSER, Conodonts from North Cornwall



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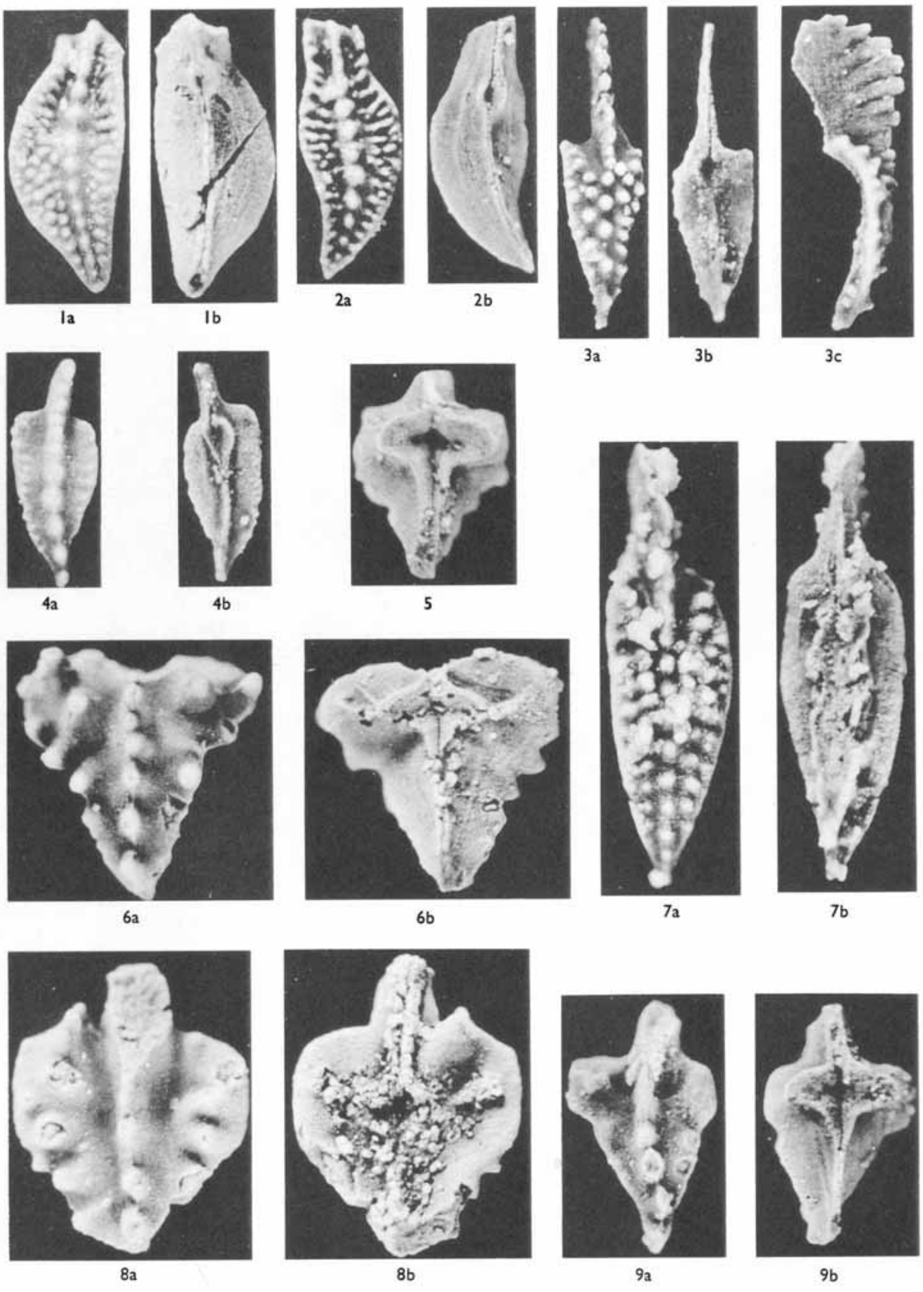

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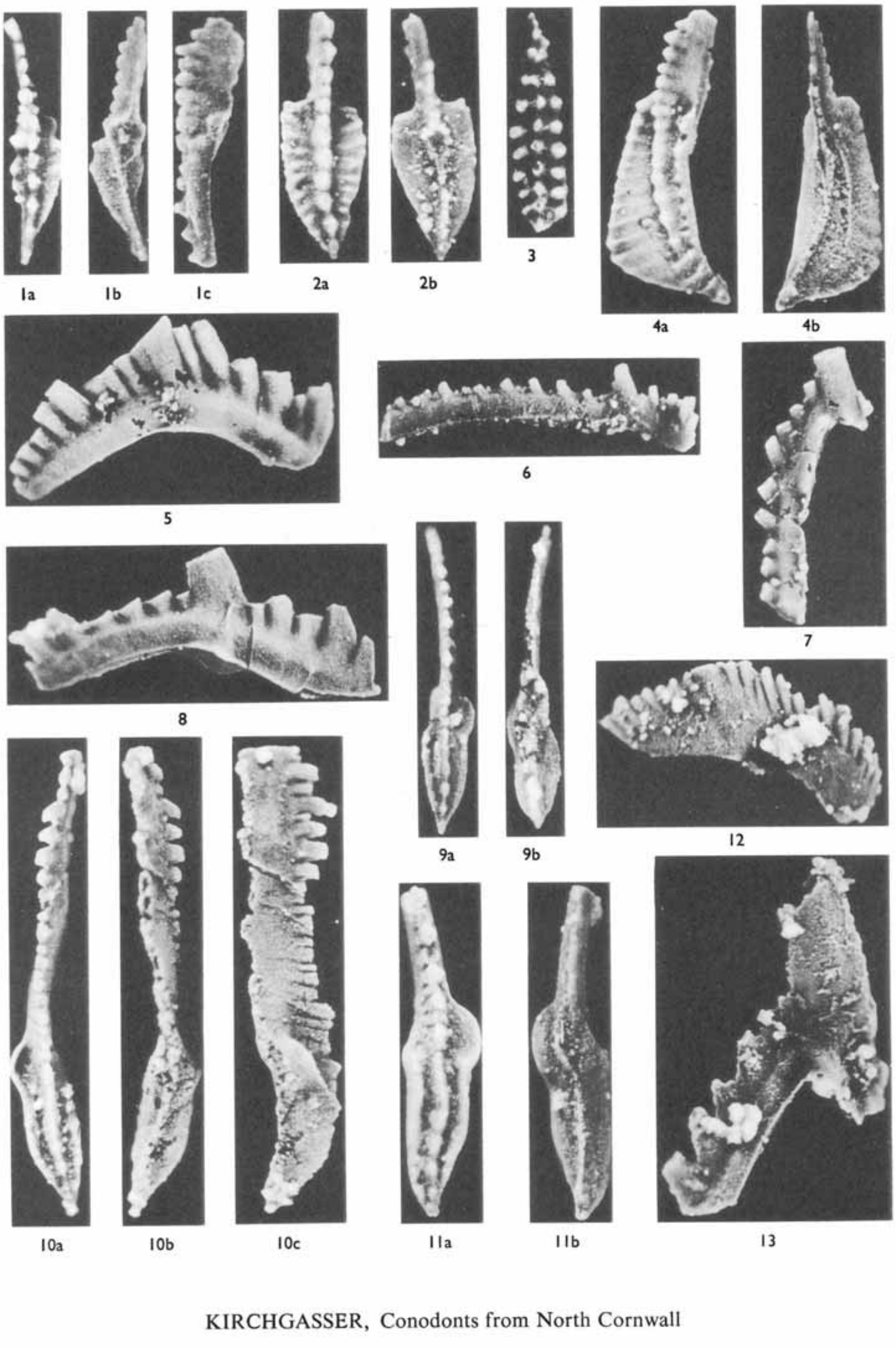

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